[0040] The surge protector **100** makes use of tight fitting joints and large press forces to maintain high pressure joints that aid in achieving a relatively great passive inter-modulation (PIM) distortion performance. Component wall thickness and joint designs are unique and ensure that the assembly of the surge protector **100** has a relatively high manufacturing yield with exceptional PIM performance, and that the device maintains its PIM performance throughout the life of the device.

[0041] For example, the housing **106** may be designed such that a relatively large amount of force, such greater than 100 pound-force, greater than 300 pound-force, or greater than 500 pound force, is required for the second portion **110** to be press fit within the first portion **108**. This relatively large amount of force causes the first portion **108** to resist separation from the second portion **110** under normal operating conditions. In order to further improve PIM distortion performance under various conditions, the first portion **108** may have a radial thickness that is sufficiently great to resist a change in dimensions due to normal changes in temperature and pressure.

[0042] Operation of the surge protector **100** will now be described. In some embodiments, the surge protector **100** may operate as a radio frequency (RF) coaxial transmission line in the 698 MHz to 2.7 GHz frequency range. The surge protector **100** bidirectional broadband frequency response may have a return loss of greater than 26 dB and an insertion loss of less than 0.1 dB from 698 MHz to 2.7 GHz. The surge protector **100** supports the electromagnetic field propagation in the TE_{01} (Transverse Electric field) mode in either direction, and is thus a bidirectional device. In the normal operating mode, the fields propagate from one end of the surge protector **100** to the other in the same manner as they operate in the coaxial transmission lines connected on each end. The fields move through the center conductors **112**, **114**, the first and second spiral inductors **190**, **192**, the tube **152**, the inner coupler **116**, the outer coupler **118**, and/or the first and second dielectric materials **144**, **146** with changing geometries that provide a **5**Q ohm matching impedance. When the fields cross the inner coupler **116** and the outer coupler **118**, which have DC isolation, the fields couple to the other side via the external fields sustained in the cavity **107** of the housing **106** simultaneously with fields through the first and second dielectric materials **144**, **146**. Because of the unique inner and outer shapes and dimensions of the inner coupler **116** and the outer coupler **118**, the inner coupler **116** and the outer coupler **118** pass the electric fields from one side to the other with a relatively excellent match and relatively little energy reflection, resulting in a very low insertion loss of less than 0.1 dB, and a relatively high return loss of well over 26 dB (see FIG. **4**).

[0043] When a relatively large power surge (such as from lightning) propagates down the coaxial transmission line to the surge protector **100**, the surge pulses first encounter the first or second spiral inductor **190**, **192**. Because the surge has a relatively low frequency, such as around 1 MHz, the surge may travel through the first or second spiral inductor **190**, **192** to the grounded housing **106**. A majority of each of the low frequency surge signals follow the spiral inductor **190**, **192** to the grounded housing **106**. The small portion of each surge that is not shunted to ground encounters the DC block in the inner coupler **116** and the outer coupler **118**, which prevent a direct path to the other side of the coupler. However, since the combination of the inner and outer couplers **116**, **118** and the first and second dielectric materials **144**, **146** produce a relatively small-valued capacitor, some energy is coupled to the other side. This energy that passes through the inner and outer couplers **116**, **118** reaches the other spiral inductor **190**, **192** where it is shunted to ground. The result is that a relatively small portion of the surge signal gets coupled to the other side of the surge protector **100**. This relatively small portion of the surge signal is sufficiently low that it will not damage any electronic components connected to the other side of the surge protector **100**.

[0044] The unique design of the surge protector **100** using the matched DC blocking coupler shape in the cavity **107**, along with the spiral inductors **190**, **192** on each end, enables the combination of relatively high quality RF performance in the designed operating range along with a relatively great ability to shunt and block low frequency lightning surge energy. In addition, the unique mechanical design enables the surge protector **100** to be easily manufactured since its design is insensitive to expected tolerance variations in components. For example, because the hollow cylinder **136** is designed to have the axial space **165** that tapers to the point **167**, the length of the center portion **124** of the inner coupler **116** may vary without affecting performance of the surge protector **100**. The manufacturing process to produce the surge protector **100** is simplified and produces better and more consistent RF performance. For example, the process to make the hollow cylinder **136** may include forming the volume **142** using a drill, which is relatively easy and cost-effective relative to other potential methods of forming.

[0045] The center conductors **112**, **114** may each be coupled to a coaxial cable where a center pin propagates the DC currents and the RF voltages and currents to flow through the surge protector **100**. As long as the voltages are below the surge protection levels, currents will flow between the center conductors **112**, **114** and the voltages at each end will be similar. The ratio of the radius of the center pin to the radius of its surrounding shell sets a fixed impedance of the coaxial cable (such as 50 ohms). The surge protector **100** matches this impedance by setting the ratio of a diameter of the signal conductors (the center conductors **112**, **114**, the extenders **164**, **166**, and the couplers **116**, **118**) to the ground conductors (the housing **106** and the tube **152**) to correspond to the ratio of the center pen to the shell of the coaxial cable. As described above, the properties of the dielectric ring's **173** are accounted for when setting the diameter ratios.

[0046] The spiral inductors **190**, **192** operate at a matched RF impedance to conduct the RF signals between the center conductors **112**, **114** during normal operation and to allow the RF signals to pass through the surge protector **100** with minimal or no RF insertion or signal loss. The RF impedance of the spiral inductors **190**, **192** may be at least 10 times the operating impedance. For example, the RF impedance of the spiral inductors **190**, **192** may be at least 500 ohms for a 50 ohms system. In one embodiment, the spiral inductors **190**, **192** have an inner radius of approximately 62.5 thousandths of an inch (mils) and an outer radius of approximately 430 mils.

[0047] For a 50 ohm impedance with a coaxial structure, the ideal (theoretical) ratio of the inner radius of the surrounding coupler cavity tube **152** to the inner coupler diameter **162** of the inner coupler **116** is $e^{5/6}=2.301$ with an air dielectric as in the center of the surrounding coupler cavity (i.e., the space between the couplers **112**A, **112**B and